4 Woodlands

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4.1 Introduction

Woodlands are important for the provision of multiple ecosystem services, goods and benefits including timber, soil protection, flood prevention, recreation, climate regulation and wild species diversity (for both generalists and woodland specialists). Many of these services are additive and there are synergies between services rather than trade-offs, woodlands are multi-functional habitats. The environmental benefits of woodlands in Wales have been valued at £34 million (Read *et al*. 2009). A recent survey[1] demonstrated that nearly 65% of people in Wales visit Welsh woodlands regularly and 94% believe they provide a definite benefit to the local community. There are two main woodland Broad Habitats; Broadleaved and Yew Mixed Woodland and Coniferous Woodland. In Wales, only Broadleaf-dominated Woodland is native, and this type is the main focus of nature conservation interest. It includes seven Priority Habitat types recognised in the UK Biodiversity Action Plan (Wet Woodland, Lowland Mixed Deciduous Woodland, Lowland Beech and Yew Woodland (confined to South Wales), Upland Mixed Ash Woodland and Upland Oak Woodland accounting for approximately 50% of semi-natural woodland (Russell *et al*. 2011), Wood Pasture and Parkland and Traditional Orchards) and Broadleaved, Mixed & Yew Woodland is recognised as a feature of interest on many SSSIs. Woodlands in Wales vary in size and distribution; areas of semi-natural and Ancient Woodland tend to be small and fragmented. There are also areas of Coniferous Woodland particularly located on poorer soils in upland Wales. The ecosystem services provided by Broadleaved Woodland and Priority Habitats tend to be more focused upon cultural services, aesthetic qualities and wildlife conservation and less on timber production, although there is activity in Wales to encourage sustainable management of Broadleaved Woodlands for environmental, social and economic outcomes[2]. Modified habitats and plantations, although less valuable for biodiversity, can still provide education and recreational opportunities as well as timber production, soil protection and flood prevention. As well as the area Broad Habitats woodland services and species are also represented in woody linear features (hedgerows and lines of trees) and smaller point features (individual trees including veterans and small clumps of trees and scrub). These features are extremely important in connecting woodland habitats within a landscape and used for shelter, dispersal, habitat by many species. An analysis of potential expansion of existing woodland and establish streamside corridors under low, medium and high uptake scenarios estimated a potential 10,000 additional hectares of woodland from these options alone (Emmett et al. 2014). Veteran trees are also important for species diversity, they are often more likely to be found in non-woodland situations (Read 2000) in open parks and wood pastures but may still be found within woodland. The UK has a relatively high density of veteran trees and it is a conservation priority to protect them.

Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards, only Scotland has a higher total woodland cover however this is a consequence of the much higher percentage cover of Coniferous Woodland there than elsewhere (Smart *et al*. 2009). About 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations (Russell *et al.* 2011).

[1] http://wales.gov.uk/newsroom/environmentandcountryside/2013/130910woodlands/?lang=en
[2] Coed Cymru http://www.coedcymru.org.uk/

4.2 Achievements of the GMEP project in Year 2

- The GMEP project is using a combined survey and modelling approach to identify the benefits of Glastir options at the national scale. Progress to date:
- Field protocols implemented for recording of woodland habitats and species in GMEP 1km survey squares which includes mapping of woodland habitat, dominant species, management information, land use, vegetation plots in small and large woodland patches and along woody linear features and bird and pollinator recording in 150 1km squares.
- Analyses of long term trends in woodland extent and condition using GMEP data alongside data from other surveys
- Assembly of Glastir Woodland data to analyse changes in woodland extent and condition and impacts on other environmental and biodiversity response variables.
- Developed a woody cover product to enable scaling from GMEP squares to larger scales
- Explored habitat connectivity metrics to develop methods for assessing impacts of Glastir options on connectivity of woodland habitats.

4.3 Findings in Year 2

4.3.1 Extent

- The area of woodland has increased in Wales over the past thirty years (Figure 4.9.2.1, Table 4.9.2.1) with an increase to 2014 (recorded by both GMEP and the National Forest Inventory (NFI)). Both Broadleaved and coniferous woodland types have increased in area.
- GMEP estimates the total area of all woodland in Wales to be 346 000ha (187000ha Broadleaved and 159,000ha Coniferous Woodland) (Figure 4.9.2.1, Table 4.9.2.1), this is 16.3% of Wales in 2013/14. This compares to 10% in England and approximately 15-18% in Scotland.
- NFI estimate the total area of all woodland in Wales in 2014 to be 306,000 ha, 14.8% of Wales[3], 156,000ha of which is Broadleaved Woodland and 151 000ha is coniferous.
- The total area of woodland in Wales is consistent between Countryside Survey (CS) and NFI (particularly considering the large confidence intervals for the estimates), the figure for Coniferous Woodland is very similar (GMEP 159 000ha, NFI 151,000ha) whilst Countryside Survey records a greater amount of woodland as Broadleaved, Mixed & Yew Woodland relative to Coniferous Woodland. More detail is provided on the methods and results in section 4.9
- NFI estimated new planting and restocking in Wales to be 3,100 ha between the two periods 2009-2010 and 2013-2014. This is less than in previous years and a small proportion of the UK new planting (50,900 ha) the majority of which was in Scotland.

4.3.2 Condition

- Coed Cymru state that 'Following a century of neglect and plunder the majority of Welsh Broadleaf Woodlands had been left in a state of serious decline. 85% showed no significant recruitment of young trees'[4]
- The total area of woodland known to be managed to the UK Forestry Standard has increased from 123,000 ha in 2001 to at least 203,000 ha in 2014[11].
- Since 2010, there have been outbreaks of two quarantine diseases affecting tree species in Wales (*Phytophthora ramorum* and *Chalara fraxinea*). A Wales specific *Phytophthora ramorum* disease management was launched in December 2013 which establishes management zones.

[3]http://www.forestry.gov.uk/pdf/ForestryStatistics2014.pdf/$FILE/ForestryStatistics2014.pdf
[4] Coed Cymru http://www.coedcymru.org.uk/

There are also a small number of non-quarantine pests and diseases known to be affecting tree species in Wales[5].

- There is inter-annual variation in the woodland bird indicator but there does not appear to have been a significant directional change in woodland bird species abundance. It is relatively stable in contrast to the farmland bird indicator (section 4.10).
- Current sequestration from Welsh woodlands is estimated to be about 1,419 gigagrams (1,419,000 tonnes) annually. Forestry is predicted to remain a net sink for atmospheric carbon[11,6]
- There was a general non-significant downward trend in Ancient Woodland Indicator (AWI) species in large 200m^2 woodland vegetation plots between 1990 and 2007 however the number of AWI species increased significantly in the 2013/14 GMEP sample (section 4.10).
- A similar trend was seen for total plant species richness in large vegetation plots (section 4.10).
- Scores for plant species preference for light (Ellenberg) are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a decline in light score between 1990 and 2013/14 this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There has been no significant change in connectivity of broadleaf woodland between 1990 and 2013/14.
- No significant change in woody species diversity in hedgerows over the last 10-20 years has been observed. An increase in cutting of hedgerows has been recorded but large declines in new planting, layering and coppicing since 1990. An increase in the length of hedgerows becoming lines of trees also increased suggests a decline in management overall.
- Land coming into Glastir has a significantly higher length of hedgerows than that outside which needs to be taken into consideration in future assessments of Glastir impact.
- There are other relevant findings embedded within Chapter 5, Chapter 7 and Chapter 10.

4.4 Policy context

Woodland expanded significantly in Wales following the First World War (Quine *et al*, 2011) primarily as a result of increasing conifer plantations. This continued after the Second World War. Concern over the loss and degradation of ancient and native woodland led to formation of protected areas such as National Nature Reserves (NNRs) and Sites of Special Scientific Interest (SSSIs) (Russell *et al.* 2011, Latham 2005). More recently there has been a shift for new planting to be Broadleaved rather than coniferous. There is also a move away from felling in even aged stands towards maintenance of forest cover (Mason 2007). The key threats/drivers identified to Semi-natural woodland (JNCC 2007, Quine 2011) are overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic or lack of management, air pollution, landuse change, climate change and new pests and diseases. Climate change is both a threat affecting species composition and woodland condition and a driver of policy change e.g. pressure to increase carbon sequestration or increasing costs of fossil fuels and searches for alternatives may result in increased woodland planting. Although the tree species themselves being long-lived and relatively adaptable may not respond quickly to climate change, species using woodlands or those shifting niche in response to rises in temperature or changes in weather patterns (e.g. increased frequency and severity of storms) may change. There may be interactions between threats e.g. tree diseases are likely to have a more severe effect were trees are also suffering from climatic stress.

[5] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en

[6] http://uk-air.defra.gov.uk/reports/cat07/1407090749_Projections_of_emissions_and_removals_from_the_LULUCF_sector_to_2050-PUBLISHED_VERSION-JULY2014.pdf

The Land Use Climate Change report[7] recommended an expansion of woodland over 20 years by about 100,000ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate. This initiative would create a Greenhouse Gas (GHG) sink and a fuel wood potential. They also recommended management to ensure that woodlands do not become an annual GHG source and that Welsh woods are managed to optimize long term GHG abatement.
Tree disease and tree health has risen sharply up the political agenda recently with the spread of diseases e.g. *Chalara fraxinea*, *Phytopthora ramorum*, sudden oak death, Dothistroma red band needle blight, bleeding canker and the high number of potential threats that could adversely affect a number of species. *Phytopthora ramorum* was first found in larch trees in Wales in May 2010, since then the disease has spread across all of South Wales, to the west and a few sites in the north, a survey in May 2013 identified some new sites. Many larch trees have been felled and more areas are showing signs of infection and will require management (e.g. Cwmcarn forest, Bwlch Nant-yr-Arian near Aberystwyth). NRW has drawn up a disease control plan[8]. *Chalara* is also an issue and has been found in newly planted sites in Wales and more recently in the wider environment[9].

There is an increasing interest in the extent to which woodlands are functionally connected (Quine *et al.* 2011) and policy for new planting tends to be focused on increasing connectivity within a landscape. Glastir has a series of options specifically designed to address connectivity which have multiple aims and benefits; to allow the spread of native trees connecting woodland components in the landscape, to enhance the character of the landscape, to encourage habitat diversity and so species diversity, to sequester carbon, to act as a buffer for fields and to increase the extent of woodland.

The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy[10]. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat diversity and species, sustainability of woodland management, carbon balance, tree health, local benefits of woodland, accessibility, value of wood and water management; spanning the range of social, economic and environmental benefits[11].
Other policy drivers which may affect woodland include the water framework Directive, and strategic environmental impact assessments and the Rural Development Program. In Wales, the Glastir scheme is a significant component of the Rural Development Program and therefore contributes to fulfilling a number of statutory obligations and targets relevant to biodiversity derived from agreements at global (Aichi targets), European (European Union Biodiversity Strategy (EUBS) plus Habitats and Birds Directives) and UK levels (Wildlife and Countryside Act and Natural Environment and Rural Communities Act) which will apply to woodland habitats. Glastir has a specific Woodlands element which includes options on creating and managing woodland (see 4.5)[12].

[7] Land use Climate Change report to Welsh Assembly Government 2010. http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/landuseclimatechangegroup/?lang=en
[8] http://naturalresourceswales.gov.uk/our-work/policy-advice-guidance/phytophthora-ramorum/?lang=en
[9] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en
[10] http://wales.gov.uk/topics/environmentcountryside/forestry/woodlandsforwales/?lang=en
[11] http://gov.wales/statistics-and-research/woodlands-wales-indicators/?lang=en#/statistics-and-research/woodlands-wales-indicators/?lang=en
[12] http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/glastirwoodland/?lang=en

4.5 Aims of Glastir for Woodlands

Glastir has a Woodlands element which has been designed to support land managers to create new woodlands and manage existing woodland to promote ecosystem services; biodiversity, water, carbon, landscape, historic features and access. The Woodland element provides area and capital grants, these can be applied to land managers in Glastir entry who do not enter Glastir advanced or land managers including farmers and woodland only holders who do not hold a Glastir entry contract. There are options under the Glastir entry and advanced schemes that apply to woodland. Glastir Woodland management options include:

- Thinning-allowing more light to enter the woodland top improve ground flora and natural regeneration
- Restocking- improving species diversity
- Infrastructure- managing previously inaccessible woodlands
- Boundary work- to stock proof woodlands or improve stock management
- Protected and priority species- grants to conserve important species
- Vegetation management- to control invasive and exotic plants
- Pest control- including grey squirrels and deer
- Public access- to improve woodland access and provide visitor information

There are also woodland creation options:

- Small Simple Woodland (Max 0.5ha)
- Basic Mixed Woodland
- Enhanced Mixed Woodland
- Native Woodland – Carbon
- Native Woodland – Biodiversity
- Wildlife corridors including trees and shrubs
- Allowing woodland edge to develop out to adjoining field
- Planting and regeneration

The Minimum application area for the top five bullet points varies between 0.1, 0.25 and 0.5ha depending upon the option.

4.6 Benefits from options / past schemes.

In Wales, funding from agri-environment schemes (AES) that could be related to woodland management has been available since the early 90s including ESAs, the Habitat Scheme, Woodland Grant scheme, Farm and Conservation grant scheme, Tir Cymen, Tir Cynnal, Tir Gofal, Better Woods for Wales and now Glastir. A few key results include

- Tir Gofal has been largely successful in maintaining the condition of woodlands and parklands. In woodland light grazing produces the most positive change[13].
- The area of farm woodland within a grant scheme doubled between 2000 and 2012, principally due to a large area of woodland within the Tir Gofal agri-environment scheme[14].

4.7 Methods

4.7.1 Woodland recording methods- General

4.7.1.1 Habitat mapping

In the GMEP field survey every habitat within the GMEP 1km survey square is mapped onto a field computer with a bespoke GIS system, this includes areas above 20m x 20m in size, as well as linear features such as hedgerows, smaller patches are not mapped but vegetation plots may be placed in

[13] http://wales.gov.uk/docs/drah/publications/130917report1habitatsen.pdf
[14] http://wales.gov.uk/docs/drah/publications/130514woodlandforwalesindicators2012en.pdf

these or some may be described as point features. Woodland is defined as 'over 25% canopy cover of trees or shrubs over 1m high'. It is then classified using a vegetation key to a Broad or Priority Habitat classification, for woodland this is either; Broadleaved, Mixed & Yew Woodland or Coniferous Woodland. Each woodland parcel is also given a structure code as to whether it is Woodland/Forest, a belt of scrub, a Belt of trees, a clump of trees, Dead lying trees, Dead standing tree(s), a Patch of scrub, Ride/firebreak, Scattered scrub or trees (2-5, >6).
As with mapping of the other habitats 2-4 dominant or characteristic species are chosen to represent the parcel and presence and cover recorded. There are additional attributes which may be added by the surveyor to describe the woodland environment. These include;

- Deer fences
- Felling/Stumps
- Fenced (single trees)
- Grazing (stock)
- Grazing/browsing (non-stock)
- Grey squirrel damage
- Natural regeneration
- Open glade and rides
- Pheasants and pheasant pens
- Planted
- Pollarded/Shredded
- Regrowth - cut stump
- Signs of recent management
- Staked trees
- Tree protectors
- Underplanting
- Windblow

They will also be given a use code as to whether the use is Landscape, Nature conservation, Public recreation, Sporting, Shelterbelt or Timber production.
Surveyors also record linear features that pertain to forestry e.g. hedgerows, lines of trees. A lot of additional detailed information is captured on these important landscape features including the base height, most common (modal) diameter at breast height (DbH), historic management, staked trees, presence of tree protectors, whether there is a margin on each side and the species and proportion. Individual trees, scrub, clump of trees, scattered trees, scattered scrub, patch of scrub, dead standing trees and dead lying trees may be recorded as point features, additional information added to this survey asks for evidence of habitat boxes and signs of disease. When recording veteran trees surveyors are asked to identify the species, the modal DbH, the type (standard, pollard or lay), whether epiphytic species are present, the % of the canopy that is live, whether there are dead or missing limbs, tears, scars, lightning strikes, hollow trunk or rot.

4.7.1.2 Vegetation plots

Surveyors have to set up new vegetation plots in the GMEP 1km survey square. Some of these are randomly located and according to strict protocols and would likely sample different woodland features including area plots from 2m x 2m in size to large area plots of 200m^2 (years 1 and 2) which could be placed within Woodland, and Hedgerow plots and Boundary plots 1 x 10m that sample woody linear features. Other plots (Y plots) could be selected according to the requirement to capture information on potential Glastir prescriptions. The surveyors did not have the information on management of the land within a square (in years 1 and 2) but suggested locations for vegetation plot placement applicable to woodland were given.

4.7.1.3 Animal, soil and freshwater sampling

Bird and Pollinator surveys took place within and outside of woodlands as did soil sampling, streams and pond surveys. This provides a population from which woodland change can be followed within the context of its surrounding landscape.

4.8 Introduction to analyses

We have explored a series of questions identified as being the most critical for woodlands. These include the area extent of woodlands and how this has changed over time, here we compare findings from GMEP with the Forestry Commissions' national statistics calculated from NFI data. The condition of woodland has also been analysed using a number of indicators identified from GMEP data; these include plant species diversity, the richness of Ancient Woodland Indicator Species, average preference of light for plant species to indicate level of management or successional stage, abundance of woodland butterflies and woodland birds, trends over time in these indicators have been presented and analyses looking at land under Glastir management for woodlands and outside Glastir carried out. There are several analyses that look at co-benefits of multiple indicators (i.e. where you can get win-wins or trade-offs) and how they vary with the amount of land under woodland management

4.9 Is woodland cover increasing or decreasing?

Of the UK countries, Wales has the highest percentage cover of Broadleaved, Mixed & Yew Woodland although this is low by European standards. Woodland is a very important habitat for biodiversity, 210 (39%) of the Section 42 species of principal importance for conservation of biological diversity in Wales either rely on woodland habitats, or could potentially be affected by silvicultural operations. The key threats/drivers identified to Semi-natural Woodland are overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic or lack of management, air pollution, landuse change, climate change and new pests and diseases. Climate change is both a threat affecting species composition and woodland condition and a driver of policy change. The Land Use Climate Change report (2010)[7] recommended an expansion of woodland over 20 years by about 100,000 ha (mainly deciduous but with a proportion of conifer) with tree provenance adapted to the projected climate.

4.9.1 Methods

- The Habitat mapping data gives us an area extent of woodland within the sample squares. The national extent of woodland can then be estimated from the sampled survey data using a statistical approach based on the sampling design within landclasses (created using variables such as geology, soils and climate). The area was calculated for each of the Land Classes in Wales. The estimation of the total area of each Broad Habitat in a Land Class involves multiplying the mean area of woodland in the GMEP 1km survey square in a Land Class, by the total land area in the Land Class, excluding unsurveyed urban land and land below the mean high water mark. The estimates of the area of Woodland for Wales were achieved by the summation of the Land Classes found in each Broad Habitat for each survey year.
- Different methods are used to record woodland in GMEP and the NFI, as mentioned above GMEP records Broad and Priority Habitat woodland, the NFI has 9 forest types (including Broadleaved, Coniferous, Mixed, Coppice, Shrub land *etc*.). GMEP (and CS) record smaller patches of woodland than the NFI, the minimum mappable unit is 20m x 20m compared to the FC 0.5 ha (either under stands of trees or with the potential to achieve tree crown cover of more than 20% of the ground). This is consistent with recording more Broadleaved woodland as there are likely to be small woodlands and clumps of trees consisting of Broadleaved trees that wouldn't be captured by NFI recording. Another methodological difference is that GMEP (and

Countryside Survey CS) record Land cover rather than land use so if an area has been clear felled and there is another habitat present then that is recorded rather than woodland. The Forestry Commission record land use so if it is within a woodland cycle it is recorded as woodland even though the current land cover is another habitat. The Woodlands for Wales indicators 2013/14 comments that some of the woodland increase shown in the FC figures may be due to improved measurement techniques.

4.9.2 Results

The area of woodland has increased in Wales over the past thirty years (Figure 4.9.2.1, Table 4.9.2.1). Both Broadleaved and Coniferous Woodland types have increased in area. The area of woodland estimated from the GMEP sample in 2013/14 is more than 50,000 ha greater than the estimate for Countryside Survey (CS) in 2007. A more moderate increase is shown in Forestry Commission figures (19,000 ha) but it is likely that woodland area has increased, possibly the larger increase in GMEP is due to an increase in smaller woodlands which are more likely to be mapped in GMEP and CS.

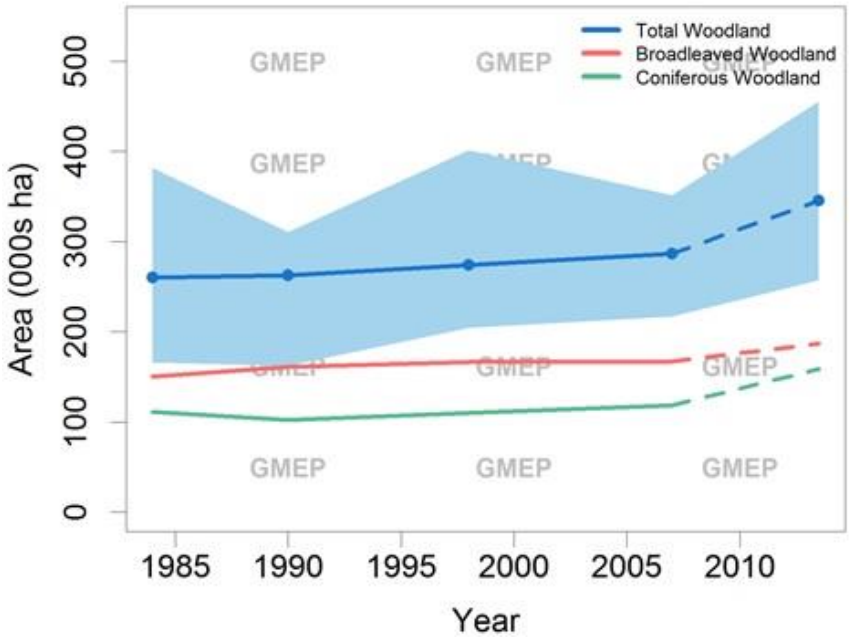

Figure 4.9.2.1 *The area of woodland in Wales over time, created by national estimates from field survey (CS and GMEP)*

Year	Total Woodland '000s ha	Lower confidence interval 2.5 %	Upper confidence interval 97.5 %	Broadleaved Woodland '000s ha	Coniferous Woodland '000s ha	FC year	FC Total Woodland '000s ha
1984	260	166	381	150	111	1980	241
1990	262	162	311	161			
1998	274	204	401	167	110	1995 -99	287
2007	287	217	351	167	119		
2013/14 GMEP	346	257	456	187	159	2014	306

Table 4.9.2.1 *Area of woodland in Wales, data presented from CS, GMEP and the Forestry Commission (FC)*

4.10 Is Woodland condition improving?

Woodland condition can be measured in different ways. The Welsh Government strategy 'Woodlands for Wales' was published in 2001 and revised in 2012. It promotes the design and management of woodlands to provide a wide and balanced range of ecosystem services. A set of 23 indicators have been developed to measure progress towards achieving the 20 high level outcomes outlined in the Woodlands for Wales's strategy. These include measures on extent, area of woodland of different types (urban, farm *etc*.) and how that is changing, habitat and species diversity, sustainability of woodland management and tree health using data from the Forestry Commission and other sources. In the GMEP field survey a number of different measurements are taken which report on woodland condition, these could complement the current indicators (the BTO woodland birds data is used in the Woodland indicators), a selection of these are shown below. They are weighted towards biodiversity and habitat quality.

4.10.1 Methodology

Woodland condition can be measured using a number of different indicators. The indicators shown here are all biodiversity based, some taken from field survey vegetation plots from GMEP and the Countryside Survey and some square level metrics on woodland butterfly and bird diversity using long term data from the Biological Records Centre (BRC) and British Trust for Ornithology (BTO) surveys respectively. Results are shown from two sizes of vegetation plot 200m^2 and 2m x 2m (y plots) where the Broad or priority habitat was a woodland type. The larger plots are randomly placed within a GMEP 1km survey square, the 2m x 2m plots tend to be associated with small habitat fragments and priority habitats. Within the vegetation plots all higher plants were recorded to species level and both canopy species and ground flora have been recorded. The indicators; total species richness: the total number of plant species in a plot, Ancient Woodland Indicators; the number of species associated with Ancient Woodlands (agreed lists with conservation agencies and British Botanical Society) and Light scores (Ellenberg); each plant has an agreed light score indicating its preference for light. These have been calculated as an average for each vegetation plot. Countryside Survey data has been used for the historic vegetation data as methods are comparable.

4.10.2 Results

- There was a general non-significant downward trend in Ancient Woodland Indicator (AWI) species in the large 200m^2 woodland vegetation plots between 1990 and 2007 (Figure 4.10.2.1, Table 4.10.2.1), however in 2013/14 (GMEP) there are a significantly higher number of AWI species. In smaller plots there was no significant difference between years.
- There was no significant change in total plant species richness in the 200m^2 large woodland plots between 1990 and 2007 although there was a downward trend, (consistent with Smart et al. 2009) however there is a higher species richness in 2013/14 (Figure 4.10.2.2, Table 4.10.2.2). There has been a downward trend in species richness between 1990 and 2007 in the smaller 2m x 2m plots (Table 4.10.2.2) which tend to be located in small habitat fragments and priority habitats, however the 2013/14 (GMEP) plots are slightly higher in species richness (although not higher than 1990).
- Scores for plant species preference for light (Ellenberg) are calculated as an average value per plot i.e. higher score= plants present prefer lighter conditions. There has been a slight decline in light score between 1990 and 2007 in the 200m^2 plots (Figure 4.10.2.3, Table 4.10.2.3) although it is much more obvious in the 2m x 2m plots (Table 4.10.2.3), this indicates that plots are becoming more overgrown with increased shading, possibly due to less management.
- There is inter-annual variation in the Woodland Bird Indicator (Figure 4.10.2.4) but there does not appear to have been a significant directional change

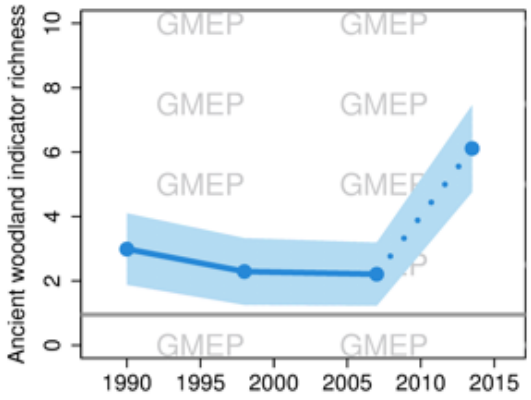

Figure 4.10.2.1 *Trend in mean number of Ancient Woodland Indicator species in 200m² plots.*

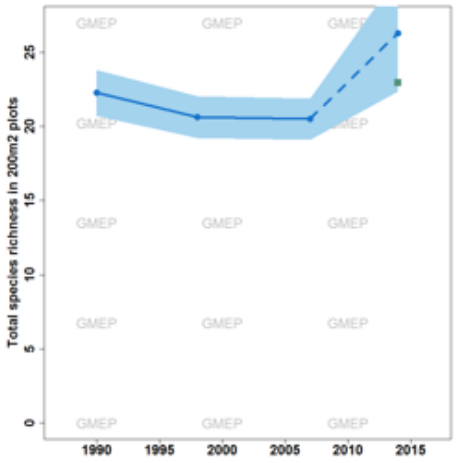

Figure 4.10.2.2 *Trend in mean Total plant species richness in 200m² plots*

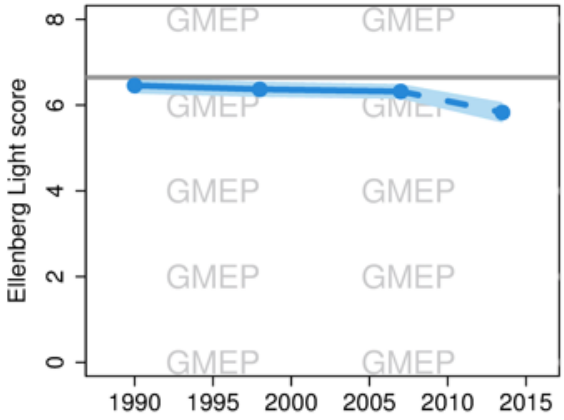

Figure 4.10.2.3 *Trend in Ellenberg Light scores 200m² plots*

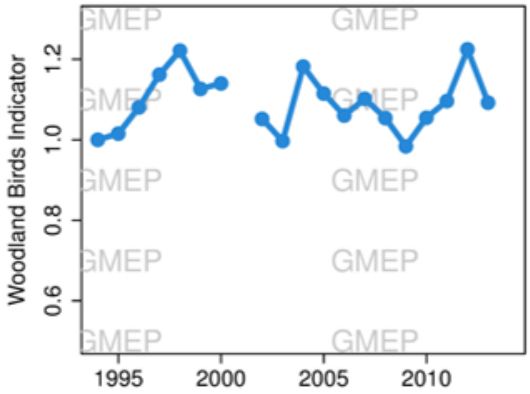

Figure 4.10.2.4 *Trend in woodland birds*

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	3.0	1.9	4.1	2.1	1.5	2.7
1998	2.3	1.3	3.3	2.3	1.8	2.7
2007	2.2	1.2	3.2	2.0	1.7	2.4
2013/14: GMEP	6.1	4.8	7.5	2.5	2.1	2.9

Table 4.10.2.1 *Mean Ancient Woodland Indicator richness each year*

There are significant differences between all CS survey years and the 2014 sample in the 200m2 plots. There was no significant difference between years in AWI indicators in smaller 2m x 2m plots.

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	25.2	21.4	29.0	12.0	10.4	13.6
1998	21.4	18.1	24.8	12.6	11.4	13.9
2007	21.0	17.9	24.1	11.3	10.4	12.2
2013/14: GMEP	26.3	22.2	30.4	11.7	10.6	12.7

Table 4.10.2.2 *Mean total plant species richness each year*

There are no significant differences between 1990, 1998, 2007 and 2014 in total species richness of 200m2 or 2m x 2m plots.

Year	Mean 200m^2 plot	Lower_est.	Upper_est.	Mean 2m x 2m plot	Lower_est.	Upper_est.
1990	6.5	6.3	6.6	6.0	5.9	6.2
1998	6.4	6.2	6.5	6.1	6.0	6.2
2007	6.3	6.1	6.5	5.8	5.7	6.0
2013/14: GMEP	5.8	5.6	6.1	5.8	5.7	6.0

Table 4.10.2.3 *Mean Ellenberg Light score each year*

There has been a significant decline in light score between 1990 and 2014 in 200m2 plots. In 2m x 2m plots the decline has been to 2007 and 2014 is not different.

4.11 What is the Coverage of Woodland habitats in the GMEP sample?

Coniferous Woodland is a commonly surveyed woodland habitat in the GMEP field survey (Figure 4.11.1). Areas in the Broad Habitat Broadleaved, Mixed and Yew Woodland have been separated from Broadleaved Woodland priority habitats so in total the area of Broadleaved Woodland surveyed is similar to Coniferous. All of the woodland priority habitats were found in the squares but the Lowland Mixed Deciduous Woodland and Wet Woodland were more frequent than the upland mixed ash, traditional orchard or Lowland Beech Woodland types.

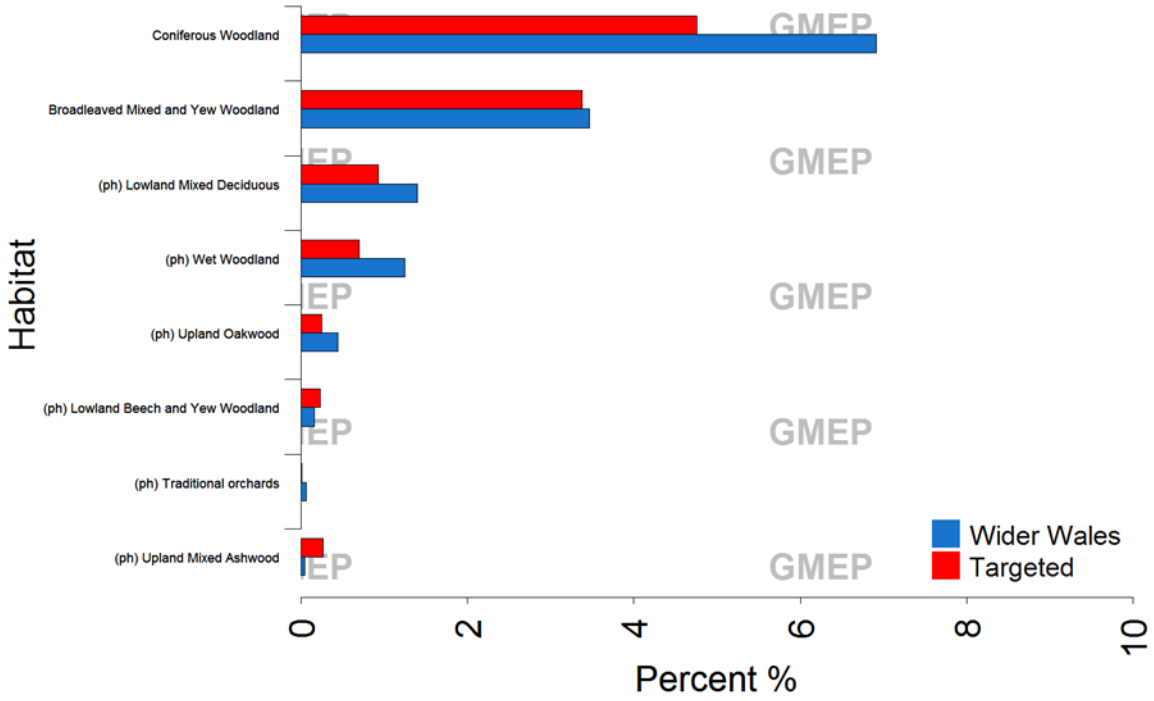

Figure 4.11.1 *Woodland habitats surveyed in GMEP*

4.12 What is the uptake of Glastir Woodland options and what extent of Woodland habitats are in the Glastir scheme?

Table 4.12.1 shows the distribution of Glastir options and landowners within the Woodland outcome for each Glastir scheme. The entry level involves the largest number of landowners unsurprisingly, however the Woodland management and advanced schemes have the greatest number of options. In terms of the extent of land 25% of land in Wales is under Glastir woodland management options and 4.1% Woodland creation. The majority of woodland management is on Broadleaved Woodland (Table 4.12.2).

	Unique option codes	Number of landowners
Entry level	8	1,183
Advanced	47	450
Woodland management	51	163
Woodland creation	5	569

Table 4.12.1 *Distribution of Glastir options and landowners uptake for each Outcome, split by Glastir element.*

	% Total land	Broadleaf Woodland habitats	Coniferous habitats
Woodland management	25	8.1	2.4
Woodland creation	4.1	N/A	N/A

Table 4.12.2 *% of habitats in Wales under Glastir Woodland options*

4.13 Is there a difference in woodland condition of land coming into the Glastir scheme relative to that outside the scheme?

The Glastir Woodland element and options within the Glastir Advanced scheme are designed to support land owners who wish to 'better manage' existing woodland (or to create new woodland) to provide beneficial outcomes for the woodland and a wider range of ecosystem services and elements of natural capital e.g. soil, water, carbon. Woodland condition can be measured in different ways. In the GMEP field survey a number of different measurements are taken which report on woodland condition which are weighted towards biodiversity and habitat quality. Glastir options for woodland management include options for woodland thinning, re-planting, fences for stock exclusion and management of scrub and invasive species.

4.13.1 Methods

The indicators shown here are all biodiversity-based, some taken from field survey vegetation plots and some square level metrics on woodland butterfly and bird diversity from the GMEP pollinators and bird surveys respectively. Results are shown from two sizes of vegetation plot 200m^2 and 2m x 2m. The larger plots are randomly placed within a GMEP 1km survey square; the 2m x 2m plots (y plots) tend to be associated with small habitat fragments and priority habitats. Within the vegetation plots, all higher plants were recorded to species level and both canopy species and ground flora have been recorded. The indicators total species richness, Ancient Woodland Indicators and Ellenberg Light score have been calculated from plots allocated to woodland broad and priority habitats. Countryside Survey data has been used for the historic vegetation trends as methods are comparable. Glastir woodland management options were identified, they are available under the Glastir advanced scheme or for land managers who are in the Glastir entry and wish to apply under the Woodlands element. The area of land that coincides with GMEP survey land was identified and then the presence or absence of Glastir woodland management options was used as a factor in the analysis.

4.13.2 Results

- There were no significant differences in Ancient Woodland Indicator species (Figure 4.13.2.1, Table 4.13.2.1), total species richness (Figure 4.13.2.2, Table 4.13.2.2), Ellenberg Light score (species preference for lighter conditions) (Figure 4.13.2.3, Table 4.13.2.3) or in the species richness of woodland butterflies (Figure 4.13.2.4, Table 4.13.2.4) in squares subject to woodland management options in Glastir and squares not under woodland management options.
- It was not expected that Glastir options would have had a significant effect this early in the process as the options will not have been in place long enough. Woodland habitats change on relatively slow timescales. This analysis provides the baseline for future analyses.

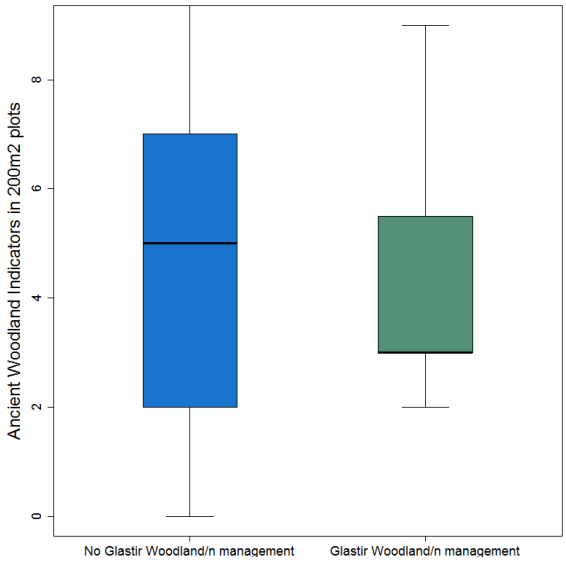

Figure 4.13.2.1 *Ancient Woodland Indicators in* 200m^2 *plots*

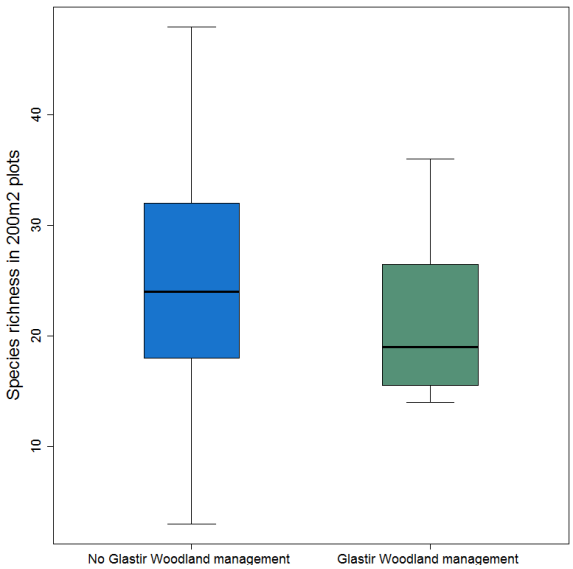

Figure 4.13.2.2 *Total species richness in* 200m^2 *plots*

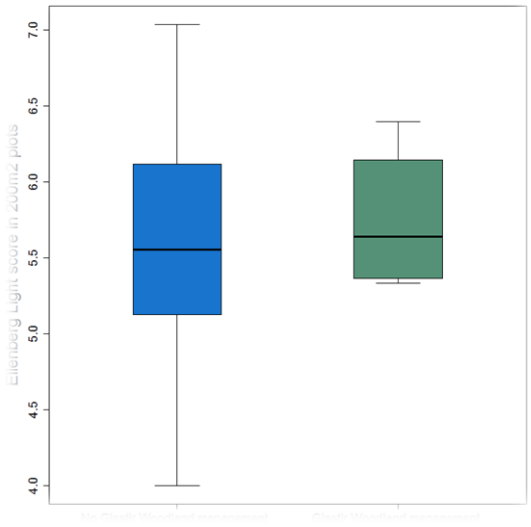

Figure 4.13.2.3 *Ellenberg Light score in* 200m^2 *plots*

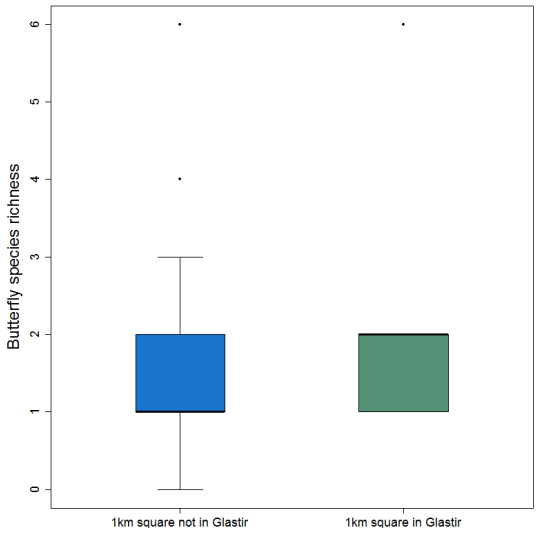

Figure 4.13.2.4 *Woodland butterfly species richness in 1km GMEP survey squares*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	5.61	4.09	7.13
1	4.55	1.27	7.84

Table 4.13.2.1 *Ancient Woodland Indicators in* 200m^2 *plots*
There is no significant difference between land in Glastir woodland management and land outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	25.22	21.40	29.04
1	22.30	14.08	30.53

Table 4.13.2.2 *Total species richness in* 200m^2 *plots*
There is no significant difference between land in Glastir woodland management and land outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	5.68	5.43	5.93
1	5.78	5.25	6.31

Table 4.13.2.3 *Ellenberg Light score in 200m^2 plots*
There is no significant difference between land in Glastir woodland management and outside

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	1.35	1.13	1.56
1	1.81	1.20	2.43

Table 4.13.2.4 *Woodland butterfly species richness in GMEP 1km survey squares*
There is no significant difference between land in Glastir woodland management and outside

4.14 What are the co-benefits of new woodlands? (e.g. Water quality, carbon, landscape?)

Using data collected in GMEP some components of natural capital; biodiversity (plants and butterflies), soil carbon, above ground carbon can be measured and have been plotted against each other in the analysis to see how they relate to each other, whether there are trade-offs or benefits between them i.e. if one variable increases as the area of woodland increases and another decreases then this is a trade-off.

4.14.1 Methodology

Data has been taken from the GMEP field survey to calculate a number of metrics at the GMEP 1km survey square level. From the vegetation plot data- plant species richness, Ancient Woodland Indicator species, pH and light scores calculated from an individual plant species' preference for either pH or light (Ellenberg), this is from all vegetation plots, not just those in woodland. The species richness of woodland birds and the richness and abundance of woodland butterflies were included as square level variables. Above ground carbon and soil carbon have been calculated using Land Utilisation and Capability Indicator (LUCI) for the GMEP survey squares (Emmett et al. 2014). These metrics have been standardised and a Canonical Correspondence Analysis (CCA) carried out to create the above response plots with the ordination score on the X axis. In future the analysis can be adapted to include the Glastir woodland creation options as a constraining variable on the x axis to identify how metrics will vary under newly created Glastir woodland. This analysis is specifically designed to identify co-benefits and trade-offs. There are other measures which it would be useful to include e.g. the landscape Visual Quality Index (VQI), freshwater measures of biodiversity and water quality, soil variables from the GMEP 1 km survey squares, however, we currently only have

data from year 1 for these measures and the sample size is reduced significantly if these are included.

4.14.2 Results

We do not yet have data on the uptake of woodland creation options in Glastir and where woodland creation options have been taken up woodland development will be at an early stage so the analysis uses data from all habitat types and plots it against the % of woodland within a square to determine what the trade-offs/co-benefits might be with increasing woodland.
Figure 4.14.2.1 shows relationships between indicators, all of the variables have been standardised i.e. plotted on a scale relative to each other, the absolute values shown on the axis are not important the relationships between them are what is of interest i.e. one variable high whilst another low = a potential trade-off.

There is a positive relationship between the number of Ancient Woodland Indicators and the amount of above and below ground carbon with the proportion of woodland in the GMEP 1km survey square. Light scores reflecting plant preference for light is negatively related to the amount of woodland which is to be expected as more above ground carbon is associated with more trees, with a greater degree of shading favouring Ancient Woodland plant specialists rather than species with a high preference for light. The pH and soil carbon are negatively related.
There are positive relationships between plant species richness and the number and abundance of woodland butterflies with the amount of woodland and some divergence with Ancient Woodland Indicator species although this levels out. Butterfly species benefit from a mixed woodland habitat with some dense understory and some rides and open spaces, whereas Ancient Woodland Indicator species are shade tolerant and do not require open glades

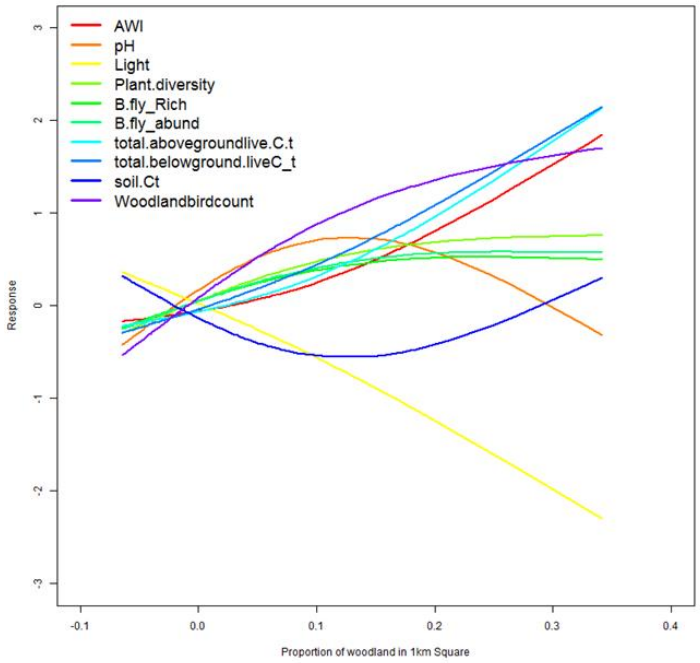

Figure 4.14.2.1 *relationships between standardised biodiversity/natural capital indicators; (AWI= Ancient Woodland Indicators, pH= pH score from plant preferences (Ellenberg), Light= plant preference for Light (Ellenberg), total.abovegroundlive.C.t= total above ground carbon tonnes per 1km square, soil.Ct= Soil carbon tonnes per 1km square, Plant.diversity= total plant species richness in 200m2 plot, B.fly_Rich= total number of woodland butterfly species in 1km square, B.fly_abund=abundance of woodland Butterfly species)*

4.15 What are the co-benefits of better management of woodlands (e.g. for water quality, carbon, landscape?)

Using data collected in GMEP some of these elements of natural capital contributing to ecosystem services can be measured and have been plotted against each other in the analysis below constrained by the % of land within a Glastir square under woodland options.

4.15.1 Methodology

This is the same as that outlined in section 4.14.1, except that the percentage of the GMEP 1km survey square under Glastir woodland management options was used as a constraining variable on the x axis, this was not found to be significant. This approach can be used in the future when woodland management options have had more time to have a significant impact.

4.15.2 Results

Figure 4.15.2.1 shows relationships between indicators such as above ground carbon and bird and butterfly diversity, all of the variables have been standardised i.e. plotted on a scale relative to each other, the absolute values shown on the axis are not important the relationships between them are what is of interest i.e. one variable high whilst another low = a potential trade-off.
There are few clear messages from the current analysis, pH and plant diversity appear to be related. Where they are higher, above and below ground carbon tends to be lower. This may indicate areas where the canopy is less dense and there is a greater amount of disturbance. Woodland birds show some association with above and below ground carbon.

This analytical method is similar to that in 4.14.1, however this analysis uses only data from woodland plots for the plot based measurements. In the future it will be possible to incorporate the woodland management options carried out in Glastir to see how co-benefits and trade-offs vary with management.

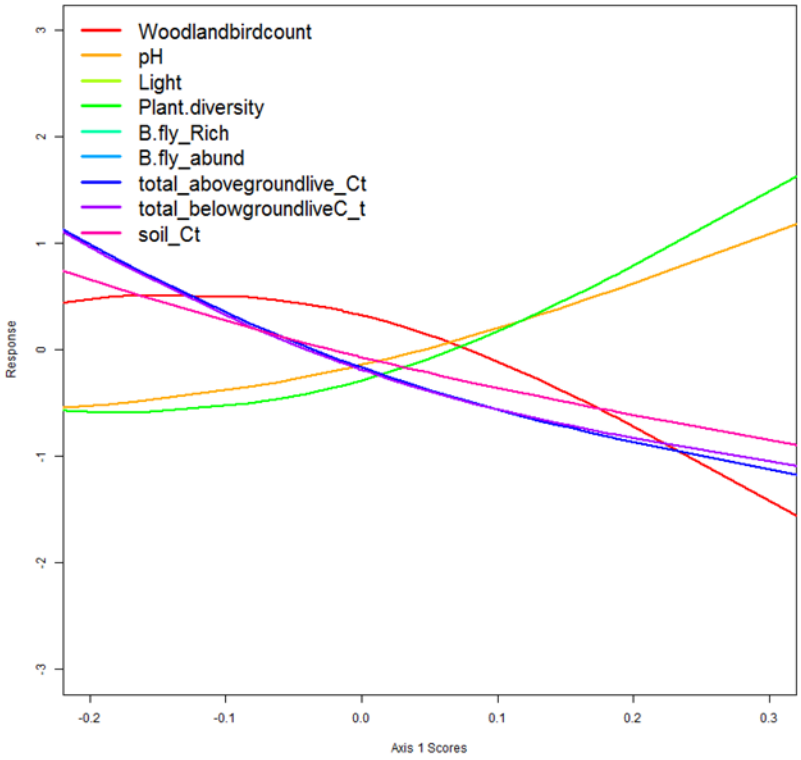

Figure 4.15.2.1 *relationships between standardised biodiversity/natural capital indicators in Woodlands using data from woodland plots;*
(Woodlandbirdcount= total count of woodland specialist birds, pH= pH score from plant preferences (Ellenberg), Light= plant preference for Light (Ellenberg), Plant.diversity= total plant species richness in 200m2 plot, B'fly_Rich= total number of woodland butterfly species in 1km square, B.fly_abund= abundance of woodland butterflies in a 1km square, total_abovegroundlive_Ct= total above ground carbon tonnes per 1km square, total_belowgroundlive_C_t= total above ground carbon tonnes per 1km square soil_Ct= Soil carbon tonnes per 1km square)

4.16 Development of a fine resolution Woody Cover Product (WCP).

Small-scale woody features such as hedgerows and small patches of trees provide valuable ecosystem services and are important for biodiversity conservation (Baudry et al., 2000). There are a range of datasets available for mapping woody vegetation in Wales, including products for mapping larger woodland areas (NFI and LCM2007) and hedgerows (EnvSys). We describe the development of the Woody Cover Product (WCP), which aims to map large hedgerows, individual trees and small patches of woodland, as well as larger woodland, across the whole of Wales. The product uses a combination of airborne radar data (NEXTMap®), optical imagery from satellites and data from the National Forest Inventory. The NEXTMap® DIFF product provides canopy height information at 5 x 5 m spatial resolution and this dataset was used to identify 'tall' features in the landscape. NDVI imagery was then used to separate tall vegetation from other tall features such as buildings and rocky outcrops. A preliminary study showed that this method was successful in identifying small-scale woody features but worked less well for large areas of woodland (Tebbs & Rowland 2014). Therefore, these larger areas were filled in using National Forest Inventory 2013 dataset to produce the final woody features product with a binary (woody/non-woody) classification at a 5 x 5 m spatial resolution. An initial version of the product has been produced for the whole of Wales. When validated against aerial photography for several test sites the product had a classification accuracy of 88 %. Work is ongoing to refine the thresholds used in the classification and extend the validation. The resulting product (Figure 4.16.1) has numerous potential applications, including investigations of habitat connectivity, modelling catchment run-off processes and quantification of carbon stocks.

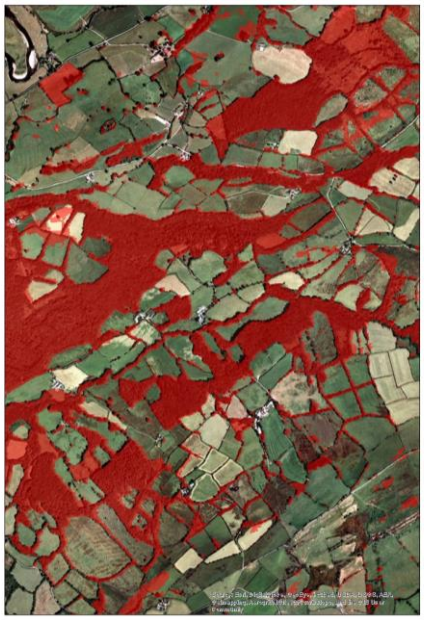

Figure 4.16.1 *A scene from the new Woody Cover Product showing the areas identified as woody cover (red areas) overlaid onto aerial photography.*

4.17 Habitat connectivity

Habitat connectivity is the ability for species to move between areas of habitat and is a function of the number and size of habitat patches and how close together they are. Habitat connectivity is important to maintain species diversity, as habitats that are highly fragmented generally cannot support as many species, however, connectivity between habitats may assist in maintaining species populations and providing resilience to changing environmental conditions (e.g. climate change allowing species to move within the landscape through habitat with equivalent microclimatic conditions). Woodland creation and maintenance is an important part of the Glastir scheme and this may result in changes in connectivity. Connectivity measures were calculated for every survey square in GMEP and Countryside Survey to look at trends in connectivity over time. Several different approaches are available to estimate connectivity from the habitat data and a number of methods were assessed

I. Euclidean distances between habitat patches- the distance in metres between the edges of each habitat patch (termed Euclidean distance because it follows the rules of Euclidean geometry
II. Least cost distances using linear feature data recorded in the field survey
iii. Least cost distances using the Woody Cover Product

4.18 What are the long term trends in Habitat connectivity of broadleaved woodlands?

4.18.1 Methodology

Connectivity between woodland areas was calculated using the Conefor program using the Probability of Connectivity measure. This measure calculates the probability that a species living in one patch of woodland can move to another patch; the probability is high if the patches are close together. The Euclidean distance between all habitat patches recorded in the field survey mapping of GMEP squares was calculated for broadleaf woodland in ArcGIS 10.2 (ESRI, Redlands, CA, USA) using the Conefor Inputs GIS extension (Jenness Enterprises, Flagstaff, AZ, USA). The probability of connectivity values are relative values taken as a proportion of the highest value therefore the y axis runs from 0 to 1. Euclidean distance was used for the long term trends because the computational

power required for least costs distance is high and it was not possible to run for all past Countryside Survey squares. We would hope to do this in future.

4.18.2 Results

There has been no significant change in the relative connectivity index of broadleaf woodland between 1990 and the GMEP survey in 2013/14 (Figure 4.18.2.1, Table 4.18.2.1).

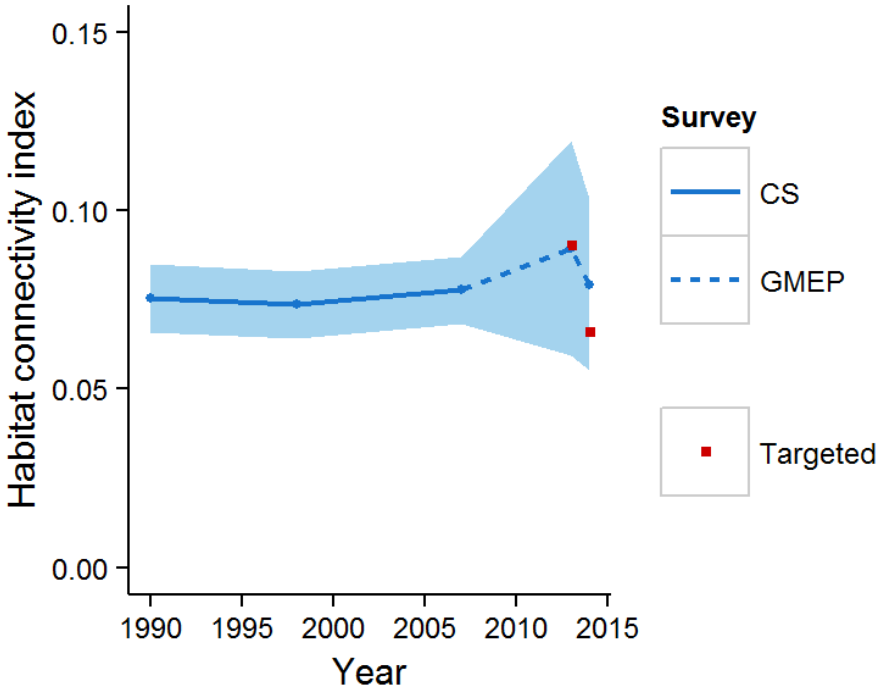

Figure 4.18.2.1 *Change in Habitat connectivity index for Broadleaved woodland over time using measure of Euclidean (straight line) distance.*

Year	Mean	Lower_est.	Upper_est.
1990: CS	0.08	0.07	0.08
1998: CS	0.07	0.06	0.08
2007: CS	0.08	0.07	0.09
2013: GMEP	0.09	0.06	0.12
2014: GMEP	0.08	0.06	0.10

Table 4.18.2.1 *Mean Habitat connectivity index of Broadleaved woodlands over time*
There were no significant differences in habitat connectivity between years

4.19 Does habitat connectivity of broadleaf woodland vary according to whether land is in Glastir?

To identify any differences in connectivity of broadleaf woodlands at the start of the scheme, connectivity measures were calculated for every survey square and connectivity compared between areas in and out of the Glastir scheme.

4.19.1 Methodology

Connectivity was measured using Euclidean (straight line) distances as above. However, using Euclidean distances to measure connectivity creates an assumption that all parts of the landscape are equally easy for a species to move through and the physical distance between habitat patches is the only barrier to movement. This is unlikely to be realistic; for example, roads and rivers provide obvious barriers to movement. More subtle barriers may also occur in the form of the habitats present in the landscape matrix. Some habitats are likely to be much easier to move through than others due to their habitat structure and food availability. For example, a species typical of broadleaf woodland might move more easily through a patch of coniferous woodland, which shares several habitat attributes, than an arable field. This information can be incorporated into the habitat connectivity metric by calculating distances between habitat patches using a least cost path instead of a simple Euclidean distance. Least cost paths are calculated as a function of the landscape occurring between two habitat patches; for example two patches separated by a habitat which is easy to move through will be calculated as being closer together than two patches separated by an impermeable habitat, even if the Euclidean distance between the patches is the same. Information on the relative ease of movement through different habitats can be obtained from the literature or by expert judgement. Here we use the results of an expert judgement of the movement of a generic broadleaf woodland species[15] to assign different weightings to the habitats in each GMEP square. A higher weighting indicates the habitat is more difficult to move through and are applied to habitats such as urban areas and freshwater.

To increase the realism of the analysis, the landscape between habitat patches included both the habitats present and any linear features. Linear features, particularly hedgerows, may be important for the dispersal of broadleaf woodland species as they can act as dispersal corridors through a landscape of otherwise impermeable habitat. The location of linear features containing woody components (i.e. excluding walls and fences) from the GMEP field survey was included in the analysis with the assumption that broadleaf species could move along linear features as easily as they could move within woodland.

Once least cost paths were calculated between all broadleaf woodland patches in each GMEP survey square the PC metric was again used to calculate the overall habitat connectivity index for each square. Again, this was scaled so that the square with the highest PC metric had a value of 1. No variation in connectivity calculated with least cost paths between GMEP squares in and out of the Glastir scheme was found, nor was there any variation between squares surveyed as part of the targeted or wider wales schemes (Figure 4.19.2.2, table 4.19.2.2).

4.19.2 Results

From the sample of 150 GMEP survey squares (including years 1 and 2 of the survey), 114 contained some broadleaf woodland and had a connectivity index of above zero. There were no differences in the relative connectivity index (PC scaled to between 0 and 1) between squares in and out of the Glastir scheme or between targeted and wider wales squares using two different approaches (Figure 4.19.2.1, Figure 4.19.2.2, Table 4.19.2.1, table 4.19.2.2). The distribution of values showed that most squares had low connectivity, with only a few squares being highly connected.

[15] This can be thought of as a species having the average requirements of all broadleaf woodland species (animals, plants etc.).

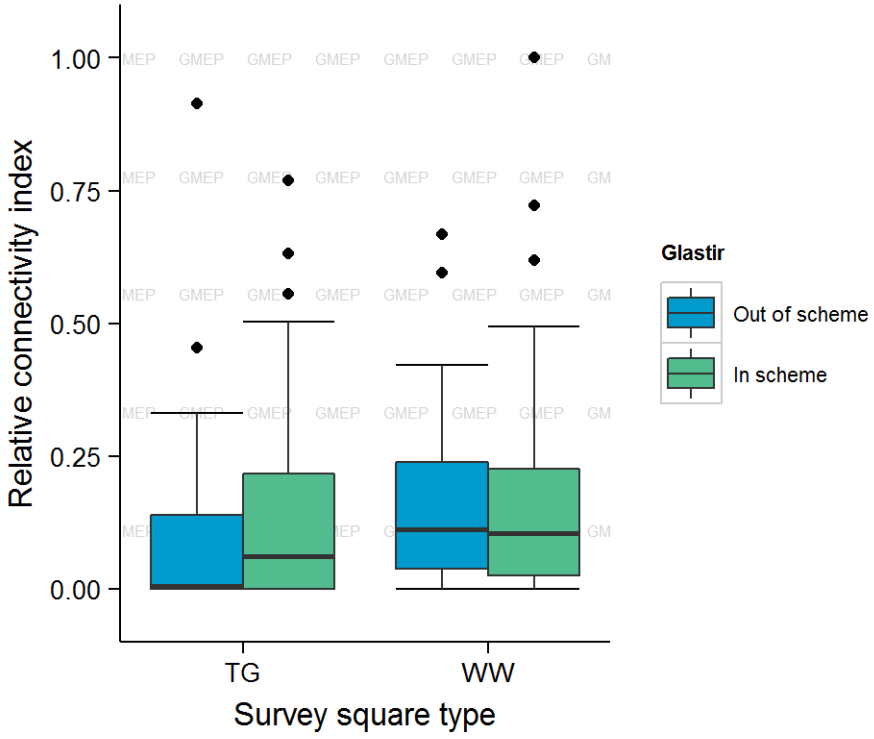

Figure 4.19.2.1. *Connectivity of broadleaf woodland habitat in Year 1 and 2 GMEP survey squares. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.16	0.1	0.23
Out of Glastir	0.15	0.07	0.22

Table 4.19.2.1 *Connectivity calculated with Euclidean distances*

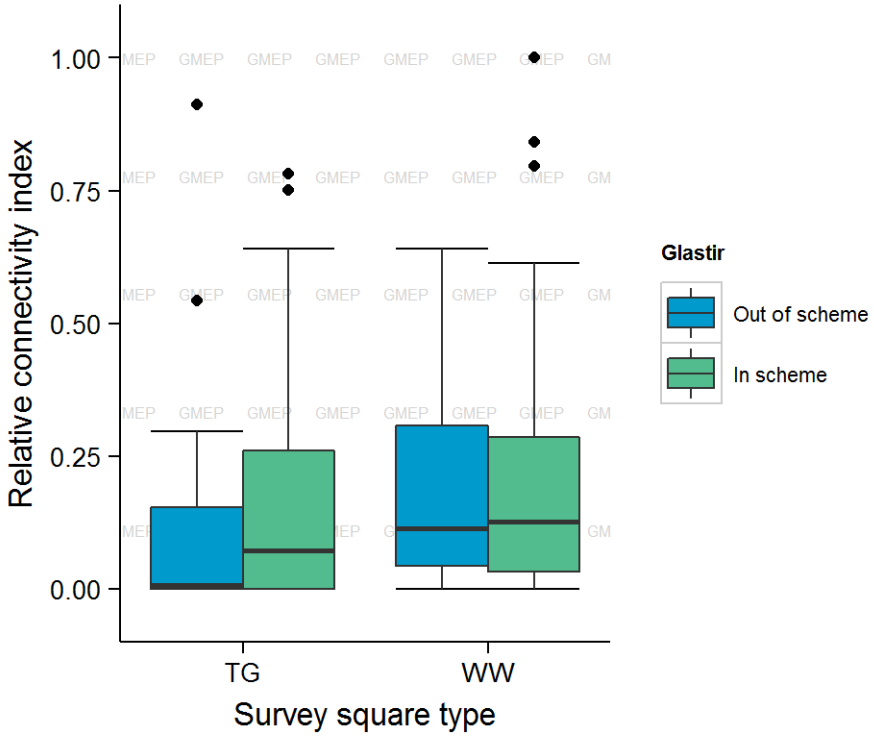

Figure 4.19.2.2 *Connectivity calculated with least cost distances*

Glastir	Estimated_Value	Lower_est.	Upper_est.
In Glastir	0.17	0.09	0.24
Out of Glastir	0.17	0.09	0.26

Table 4.19.2.2 *Connectivity calculated with least cost distances*

4.20 Does habitat connectivity of broadleaf woodland vary according to whether land is in Glastir using the Woody Cover product?

The Woody Cover Product (WCP) described above can also be used to inform least cost modelling for broadleaf woodland species. Briefly, this product produces a map of all the woody cover in a GMEP square, incorporating large areas of woodland, hedgerows and even isolated trees. These data were used in place of the linear feature data derived from the field survey to calculate least cost paths through the landscape; it was assumed that broadleaf species could move freely within the areas outlined by the WCP. The least cost distance methods is the best method for calculating a connectivity metric but does require a large amount of computational power. Including the woody cover product is not really necessary for analysing the GMEP squares on their own as we already have very good data from the field survey but when considering how best to scale up to squares where there has been no GMEP survey for instance for the work on HNV it is quite important.

4.20.1 Methodology

Habitat connectivity was calculated as in section 4.19.

4.20.2 Results

Figure 4.20.2.1 shows the results from the analysis using least cost distances calculated with the Woody Cover product, again no differences were observed between squares in and out of Glastir, or between targeted and wider wales squares. The ability to use the woody cover product to identify features such as hedgerows that contribute towards habitat connectivity will allow us to look at connectivity outside of the GMEP survey squares in the future.

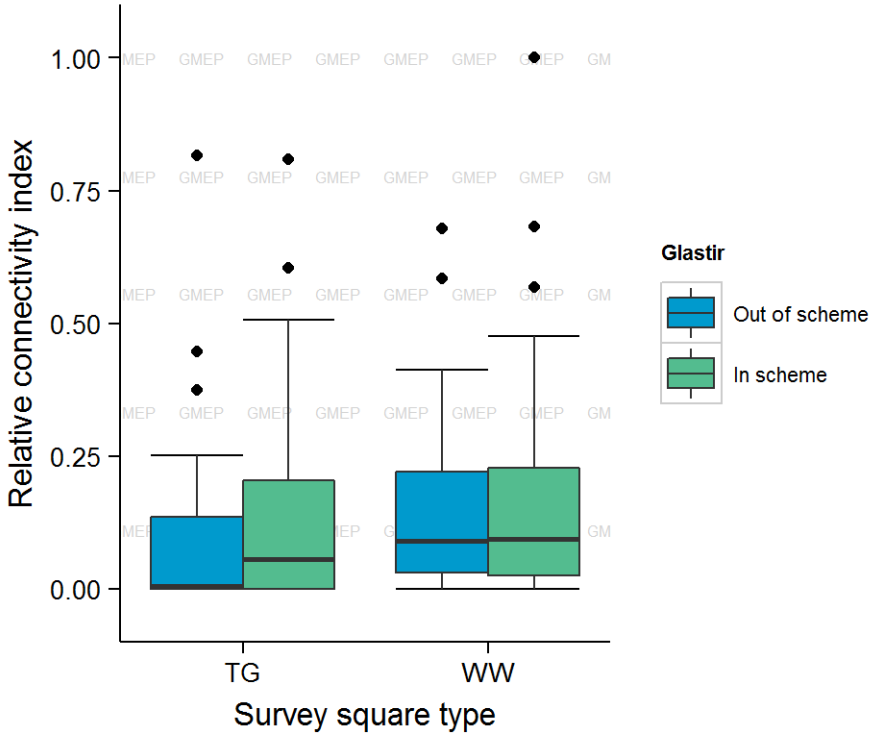

Figure 4.20.2.1 *Connectivity of broadleaf woodland in Year 1 and 2 GMEP survey squares using least cost distances between habitat patches using the Woody Cover Product. Connectivity was measured using the Probability of Connectivity metric and was scaled to between 0 and 1 to provide a relative connectivity metric.*

4.21 What are the long term trends in the length of Woody Linear Features?

Hedgerows, which incorporate both lines of trees and managed shrubby hedgerows are significant features in the Welsh lowland landscape. In landscapes otherwise dominated by pasture land, they provide habitats for a large number of invertebrate, plant, mammal, bird and even amphibian species which inhabit and use all parts of a hedgerow for shelter, food and nesting sites including the hedge base, shrubby vegetation and hedgerow trees. They provide valuable corridors between woodland areas and are particularly important in terms of connectivity for bat species which may use them for navigation, roosting and feeding. All hedgerows which consist of greater than 80% native species are Priority Habitats.

4.21.1 Methodology

Hedgerows consist of boundary lines of trees or shrubs, which include over 80% native species by cover, and which are over 20m long and less than 5m wide and where gaps between tree or shrub species are less than 20m wide. All features which fit these criteria are mapped in GMEP using a field computer and a bespoke GIS mapping system. Features are either mapped as features in which trees take their natural shape (lines of trees) or features in which trees do not take their natural shape (managed or 'shrubby' hedgerows).

Methodologies for GMEP are consistent with Countryside Survey so it is possible use data from both to determine long term trends. Note that length estimates are not national estimates and therefore not comparable with the national estimates provided for Wales in 2007.

4.21.2 Results

- There was no significant change in the total extent of woody linear features (lines of trees and hedgerows) across the period 1990 to 2007.
- There was a decrease in the length of managed hedges between 1998 and 2007 (Figure 4.21.2.1) with a large proportion of these hedges turning into lines of trees and relict hedges.
  Such a loss of features is a threat to biodiversity in the wider countryside because once managed hedgerows deteriorate into lines of scrub and relict hedge it is increasingly unlikely that they will be brought back into a management cycle. It is more likely that they will further deteriorate and will eventually be lost altogether as a woody linear boundary feature. In the GMEP sample there are more lines of trees than hedgerows.

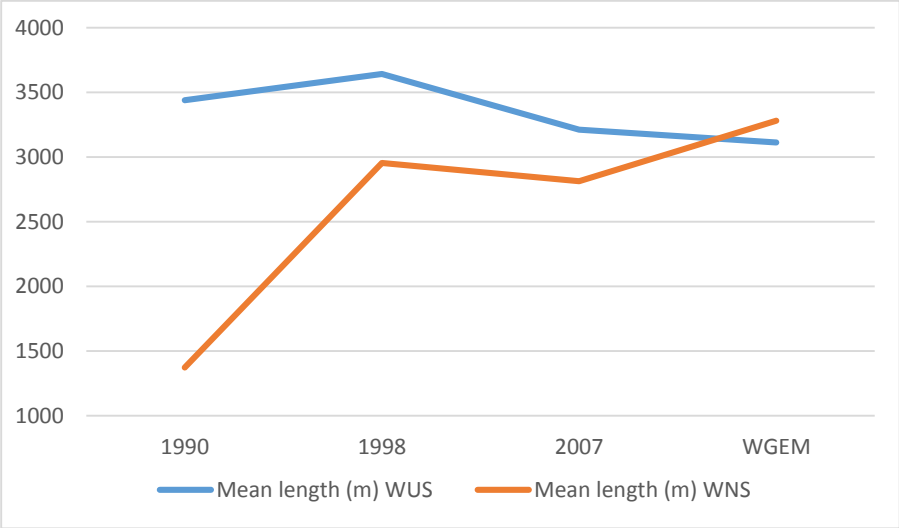

Figure 4.21.2.1 *Mean length of WUS (managed hedgerows) and WNS (lines of trees/relict hedges) in squares surveyed since 1990.*

4.22 Does the length of woody linear features vary according to whether land is in Glastir?

Hedgerows are a key focus of Glastir schemes with options for simple and enhanced hedgerow management, fencing and restoring hedgerows all available under entry and advanced Glastir. Hedgerows, which incorporate both lines of trees and managed shrubby hedgerows provide an important connectivity function in landscapes which are dominated by agriculture, particularly for species which are typical of wooded habitats.

4.22.1 Methodology

For this analysis total lengths of each woody linear feature type (see 4.21.1) per square were recorded. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the square was under Glastir management was used as a factor in the analysis. In future it will be possible to look at specific options spatially (allowing for suitable sample sizes) to assess whether a particular option is having an effect. The mean total lengths for squares containing land under Glastir agreement were compared with those not containing Glastir land.

4.22.2 Results

- There are significant differences in the mean length of linear features in a 1km square between land that is under Glastir management and land that is not in Glastir although there is more variability in the length of lines of trees than the hedgerows (Figure 4.22.2.1, Figure 4.22.2.2, Tables 4.22.2.1, 4.22.2.2).
- These results show that there are significantly more hedgerows and lines of trees in land that is being managed under Glastir. It is too early for this to be a result of Glastir management, however, it does suggest that the land going into Glastir has more hedgerows and lines of trees. It will be interesting to see how this changes over time.

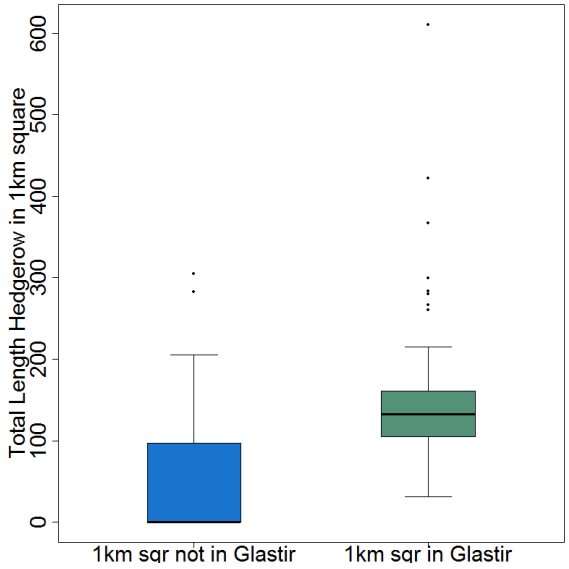

Figure 4.22.2.1 *The Total length of hedgerows in a 1km square in land managed under Glastir and land not in Glastir*

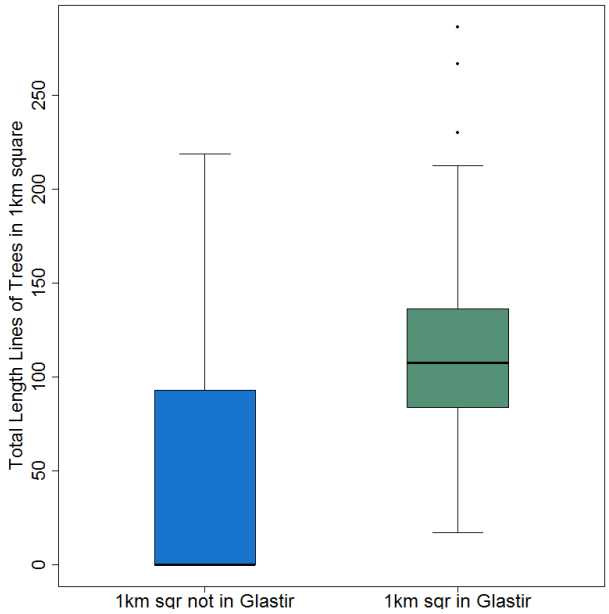

Figure 4.22.2.2 *The Total length of lines of trees in a 1km square in land managed under Glastir and land not in Glastir*

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	49.07277	30.66384	67.4817
1	150.3941	132.229	168.5592

Table 4.22.2.1 *Total Length of Hedgerow in a 1km square*

There is a significant difference between 1km squares under Glastir ownership and 1km squares not under Glastir ownership

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	46.32635	33.28281	59.36989
1	113.0464	102.0981	123.9948

Table 4.22.2.2 *Total length of Lines of trees in a 1km square*

There is a significant difference between 1km squares under Glastir ownership and 1km squares not under Glastir ownership.

4.23 What are the long term trends in the condition of priority (section 42) habitats: Hedgerows?

All hedgerows which consist of greater than 80% native species are Priority Habitats. Detailed favourable condition criteria were established for these 'shrubby' hedgerows by the Priority Habitat Steering group pre 2007, as data which could be measured from Countryside Survey (primarily from Hedgerow Diversity (D) plots).

4.23.1 Methodology

Information on species diversity of hedgerows is measured in Hedgerow Diversity plots (D) associated with both managed 'shrubby' hedgerows and lines of trees. Up to 10 D plots, each spanning the width of a 30m section along a hedgerow are recorded in each 1km square. Numbers of plots are dependent on the extent of hedgerows in a square, with no two plots being placed along the same length of hedgerow. Detailed information on species and species cover are recorded across a sample of hedges chosen to be representative of the square. General condition of mapped 'shrubby' hedgerows (rather than lines of trees) can be assessed from information on hedgerow height and evidence of management. Detailed condition criteria developed include; 1) width of perennial vegetation >1m, 2) distance to plough>2m, 3) width > 1.5m, 4) height >1m, 5) cross-sectional area >3m, 6) <10% non-native woody species, 7) base of canopy <0.5m, 8) no gaps >5m and 9) overall gappiness <10%. Detailed D plot recording to enable condition assessments of hedgerows did not begin until 2007.

4.23.2 Results

- Measures to assess whether or not a sampled hedgerow diversity plot is in good condition demonstrate that hedgerows in 2007 and hedgerows sampled in GMEP are similar in meeting structural criteria (41% in GMEP and 44% in CS 2007).
- There is no significant long term trend in the woody species richness of hedgerow diversity plots between 1998 and 2014 (Figure 4.23.2.1, Table 4.23.2.1).
- Most hedgerows are 1-2m in height (Figure 4.23.2.2, Table 4.23.2.2), this has remained fairly stable over the period 1990 2014. There has been a reduction in the number of hedgerows 2-3m in height but an increase in taller hedgerows >3m to some extent.
- Hedgerow management has increased over time (Figure 4.23.2.3, Table 4.23.2.3), with an increase in cutting in particular. There are a lower proportion of hedgerows that are newly

planted and less laying or coppicing. It should be noted that there was an increase in the length of managed hedges becoming lines of trees which indicates a decline in management overall so here the term 'hedgerows' only refers to those that have been maintained.

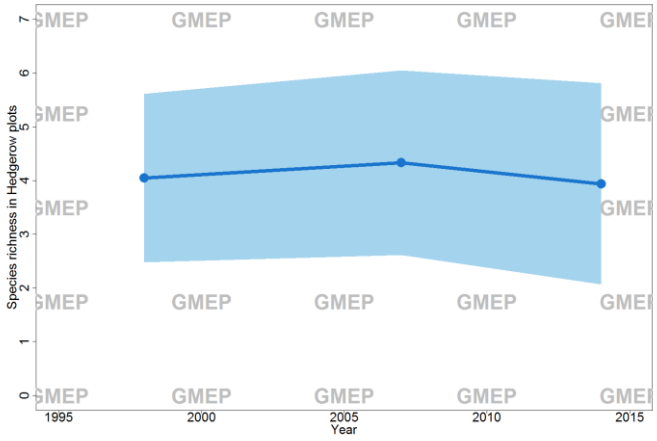

Figure 4.23.2.1 *Trends in Species richness in Diversity plots over time*

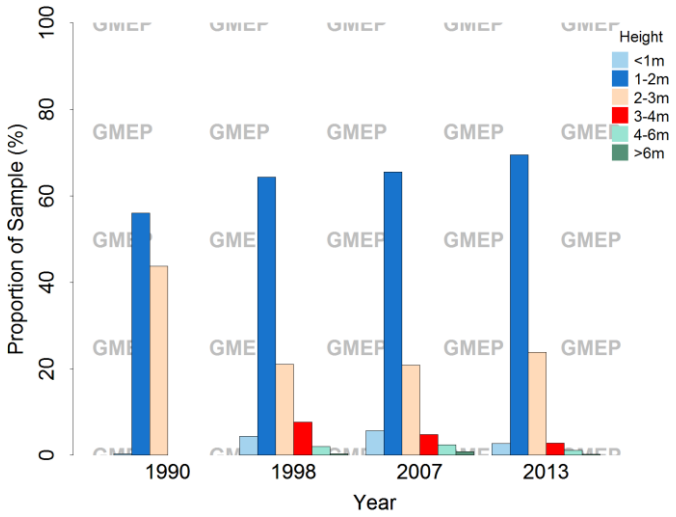

Figure 4.23.2.2 *Trends in hedgerow height categories over time*

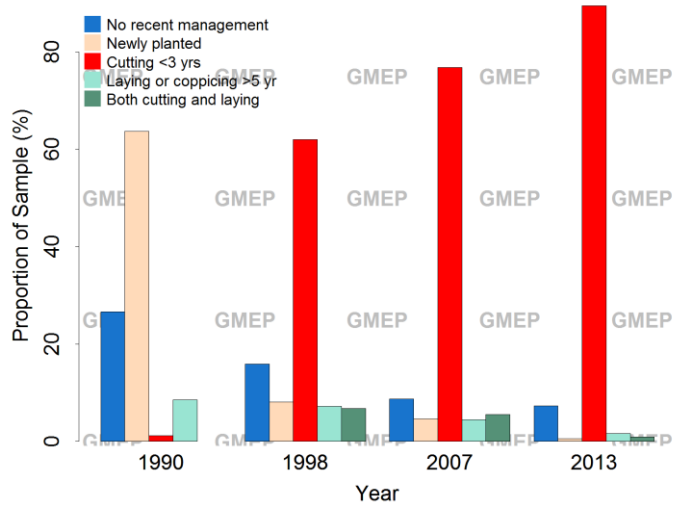

Figure 4.23.2.3 *Trends in hedgerow management activity over time*

Year	Estimated_Value	Lower_est.	Upper_est.	St Dev
1998: CS	4.04	2.47	5.61	1.57
2007: CS	4.33	2.61	6.05	1.72
2014: GMEP	3.94	2.07	5.81	1.87

Table 4.23.2.1 *The Mean number of species in a Hedgerow (D) plot from 1998 to 2014*

	proportion %			
Height	1990	2000	2007	WGEM
<1m	0.3	4.4	5.7	2.7
1-2m	56.0	64.4	65.5	69.5
2-3m	43.7	21.1	20.9	23.8
3-4m		7.7	4.8	2.8
4-6m		2.0	2.4	1.1
>6m		0.3	0.8	0.2

Table 4.23.2.2 *The proportion of managed hedges at different heights*

	proportion %			
Management type	1990	2000	2007	WGEM
No recent management	26.6	15.9	8.7	7.3
Newly planted	63.7	8.1	4.6	0.6
Cutting <3 yrs	1.2	62.0	76.8	89.5
Laying or coppicing >5 yr	8.5	7.2	4.5	1.6
Both cutting and laying		6.8	5.5	0.9

Table 4.23.2.3 *The proportion of managed hedges showing evidence of different management regimes*

4.24 How is the ecological condition of section 42 (priority) habitats Hedgerows related to Glastir?

The general condition of mapped 'shrubby' hedgerows (rather than lines of trees) can be assessed from information on hedgerow height and evidence of management and related to whether or not land is in Glastir. Condition is likely to be dependent on the length of time in Glastir and previous management. More detailed favourable condition criteria were established for these 'shrubby' hedgerows by the Priority Habitat Steering group pre 2007, as data which could be measured from D plots.

4.24.1 Methods

Information on hedgerow condition and species is measured in D plots associated with both managed 'shrubby' hedgerows and lines of trees. The land in Glastir in the entry or advanced level schemes was overlaid with the GMEP survey squares, whether or not the hedgerow diversity plot was under a Glastir hedgerow option was determined and used as a factor in analysis.

4.24.2 Results

Evidence shown below on the condition of hedgerows calculated using Hedgerow Diversity plot condition measures shows that hedgerows on land under Glastir are in better structural condition than those on land not in Glastir, however there is no significant difference in woody species richness (Figure 4.24.2.1, Table 4.24.2.1).

Table 4.24.2.2 shows that hedgerows in land under Glastir management are more likely to have had less recent management but to have shown some evidence of cutting, laying and coppicing.
Table 4.24.2.3 shows the average height of hedgerows in and out of Glastir.

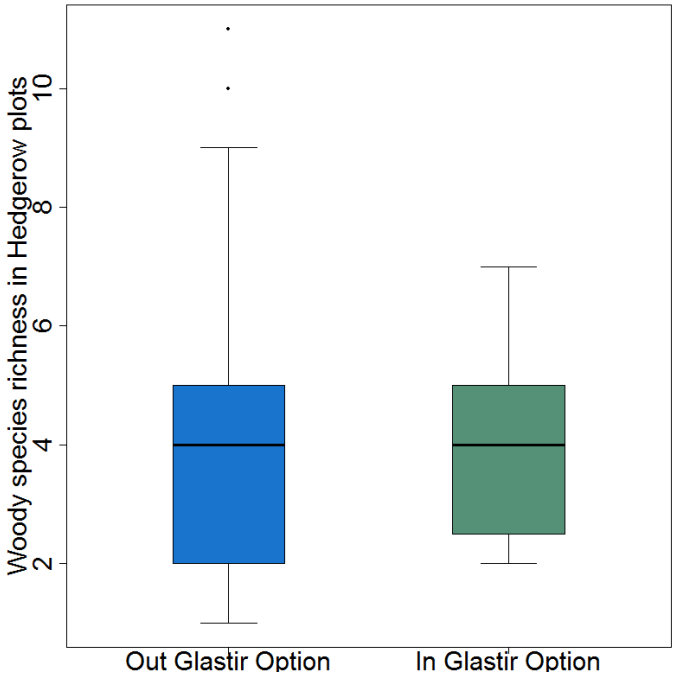

Figure 4.24.2.1 *Woody species richness in hedgerow diversity plots in and out of Glastir ownership*

D plot condition measures on D plots on managed hedgerows indicate that of the 560 plots, 229 (41%) reach the structural condition criteria set by the Priority Habitat Steering group pre 2007 (criteria 3 to 9 in methods). 41 (18%) of these plots were in squares containing no Glastir land, the remaining 88% of plots were in squares containing Glastir land. Probably as a result of the relatively small amount of arable land in Wales the number of plots reaching full condition criteria in terms of both structural condition, width of perennial vegetation and distance to plough greater than 2m was just 12 (2%). Of these plots 10 were in squares with land in Glastir and 2 were not.

Glastir	Estimated_Value	Lower_est.	Upper_est.
0	3.87	3.63	4.12
1	3.84	3.14	4.54

Table 4.24.2.1 *Woody species richness in Hedgerow diversity plots.*

There is no significant difference between land under Glastir ownership and land not under Glastir ownership.

EVIDENCE_MANAGEMENT	ANY_GLASTIR	N Obs	Length
No recent management	0	33	3265.2
	1	180	20514.2
Newly planted	0	3	121.2
	1	18	1795.8
Cutting <3 yrs	0	361	47618.8
	1	1649	242323.7
Laying or coppicing >5 yrs	0	4	238.8
	1	20	4978
Both laying and cutting	0	11	1085.1
	1	19	1939.7
Total	0	412	52329.1
	1	1886	271551.4

Table 4.24.2.2 *Management of hedgerows in and out of Glastir*

HEIGHT	ANY_GLASTIR	N Obs	Length
<1m	0	26	1994.1
	1	73	6728.6
1-2m	0	242	33051.7
	1	1356	191965.2
2-3m	0	103	13290.7
	1	383	63818.5
3-4m	0	17	1869.7
	1	56	7131.5
4-6m	0	19	1773.7
	1	15	1666.8
>6m	0	5	349.2
	1	3	240.8

Table 4.24.2.3 *mean length of hedgerow under different height categories in and out of Glastir*

4.25 Future work

- Further analysis of GMEP data:
    a. Calculation of extent of woodland priority habitats
    b. Continued analysis of trends in indicators including year 3 data
    c. Analysis of baseline in and out of Glastir including year 3 data
    d. Continued Development of woodland connectivity indicator
- Continuation of woodland topic group to discuss approaches, results and analyses with other woodland stakeholders, in the context of policy requirements and external drivers, and comparing with and complementing other existing monitoring schemes.